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Modeling Radiation Doses for a Hypothetical Contaminated Site Using RESRAD-OFFSITE Code Faisalabad, Pakistan

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ABSTRACT

Naturally Occurring Radioactive Materials (NORMs) are one of the main sources of radiation exposure to humans and environment. To access the impact of NORMs on human health and environment, different approaches (Deterministic & Probabilistic) are used globally. The radiological doses to the public from NORMs depend on the level of radioactivity, type of usage of the site, nature of the deposition and the location of the population with respect to the contaminated site. Different international organizations like International Commission on Radiological Protection (ICRP) and International Atomic Energy Agency (IAEA) had established international safety standards regarding protection from man-made and natural sources of ionizing radiations. In the current research work, the radiological doses to public, off - site, from the soil of a hypnotically contaminated area with radionuclides (40_K,137_{Cs}, 226_{Ra} *and* 232_{Th}*) at Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan has been estimated using (RESRAD-OFF) code.The radiation doses due to different exposure pathways have also been estimated. The co-relation of different exposure pathways with the doses has also been analyzed.*

1. Introduction

Building materials surrounds high levels of radionuclides especially 226-Ra, 232-Ra, 40-K and 137-Cs. These four collectively produce a considerable amount of radioactivity. In Australia, activity concentration from the stone is 4000 (Bq/kg), in the clay bricks and concrete is (1600Bq/kg). The total dose received due to the building materials is 0.5 (mSv/year) [1].

Over the years, it is also well known that the coil power-stations release more radioactivity to the environment. By burning and different useful activities of coil in some areas of the world can contain some higher levels of radioactivity of about (1400Bq/kg) [3]. The production of coal through mining gives rise to radon levels and the higher levels of radium and potassium. Residues of radionuclides settled in the waste water and rise up to the environment has been measured with the activity of 55,000(Bq/kg) of Ra-226 and 15,000 (Bq/kg) of Ra-228, in literature [1].

The mining and processing of metals ores from the earth, other than uranium also generate the large quantity of NORM's wastes. Radon exposure is repeatedly a problem in the metals mines. A survey of 25 underground mines in china exhibited six radon concentration, having activity concentration of about 1000 (Bq/m^3). In all the metals mines, the annual dose rate of (7.75 mSv/year) was found as quoted in literature [1-2].

In china, 44 coal mines (40 of which were underground), showed that the radon concentration, in 15% of them were on ground 1000 (Bq/kg). Public dose rate of exposure from uranium mining is about 1mSv/year, as quoted in literature [3].

The oil and gas production wells had shown that the long lived uranium and thorium isotopes are not organized in a manner, from the rocks that contain. However, Ra-226, Ra-224, Ra-228 and Po-210 are organized. It is well documented that total mean annual dose equivalent from oil and gas production industry is 1.72 (mSv), as quoted in literature [4].

Phosphate rocks are used in the process of fertilization, is also a source of the NORMs (uranium and thorium). Phosphate is a common constitute of fertilizers. The annual dose received by phosphate and fertilizers in Iran, in the outdoor, is to be found (0.07-0.09) mSv/year in the soil samples containing fertilizers, whereas the outdoor in infertile soil sample is (0.06mSv/year), as quoted in literature [5].

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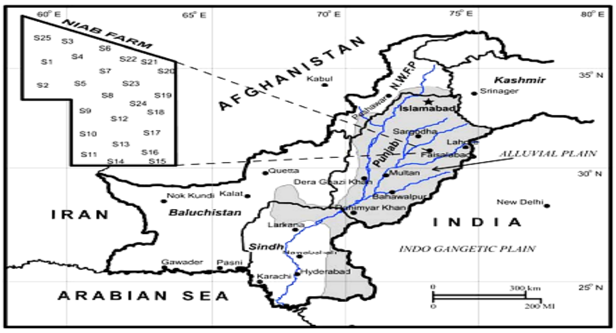

Fig. 1: The map of Pakistan showing Location of Area under Study, from literature [13]

The region under analysis involved of 100 hectors of productive soil at NIAB, Faisalabad, PAKISTAN. The location of the area as seen from Fig.1 is 31˚24´ N and 73˚05´ E [13].

2. Research Methodology

2.1 Computational Technique

RESRAD-OFFSITE code is developed by Environmental Science Division Argonne National Laboratory, Department of energy (DOE), and U.S.A for the evaluation of radiation dose and access cancer risks to an individual who directly spends their time on the primary contaminated area (onsite) or in the vicinity, of the primary contaminated area (offsite). For the execution of RESRAD-OFFSITE code, input data is required from the onsite contaminated zone (the zone in which radionuclides are presents), for its modeling. For the modeling of RESRAD-OFFSITE code [14] different site specific parameters are required.

- Radionuclide'*s* concentration in the soil
- Agricultural areas and their contribution to the doses
- Pastures, dwelling areas
- A well, and a surface water body

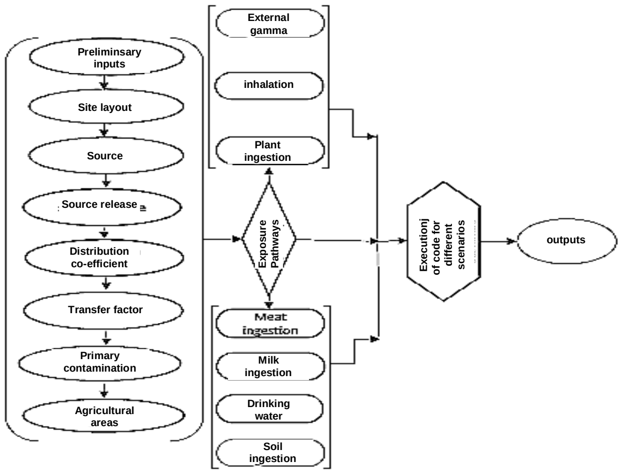

Fig. 2: RSRAD-OFF site model description

For the modeling of RESRAD-OFFSITE, there are three release models which are considered from the contaminated zone, also considering the radionuclide distribution and concentration from the contaminated zone. First model calculates the atmospheric release of the particulates due to suspension and volatile by diffusion and evapotranspiration processes. Secondly due to the erosion by run-off water and the last one is ground water release due to leaching by infiltrating water. The release rates are used by the code to compute the transportation of the contaminants and the exposure at the offsite due to the onsite contamination. Another feature of the RESRAD-OFFSITE code (Ground water transport-model),that modulate the transfer factors of the parent nuclides and as well as the daughter's nuclides (process of the decay and the growth of the radionuclides). In the RESRAD-OFFSITE model a feature of source release mechanism is also consider. For this feature two types of contaminated material are to be considered, the first one is to be capable of decaying and the other one is not capable of decaying. Therefore for this, two times-delay periods are required, the first one is when the material is not decaying or in growth and the other is the-delay when the radionuclide is decaying or growth. Another feature of the RESRAD-OFFSITE code (Area factor for offsite exposure scenario), which is defined as the ratio of calculated dose from the large primary contaminated area to elevated area (hot spot) in the primary contamination.

In the exposure scenario, the area factor can be calculated by the site specific parameters and probabilistic feature of the code. The interface of the map of the code automatically calculates radiological dose and risk,for the air and ground water transport distance. It also calculates the exposure scenario for a number of areas from a contaminated area, according to the number of user's specified conditions.

2.2 Initial Conditions and Assumptions

For the calculation of radiological doses, the geometry of the radiation source term, exposure distance between the source and the individuals and the reporting time were also considered, literature [13].

2.2.1 Source term

The source term for the estimation of radiological dose was taken from the International published data [13], as a source term, four radionuclide (K-40, Cs-137, Ra-226, and Th-232) are considered. It is assumed that the concentration of the radionuclides are uniform over the primary contamination. Three different soil layers up to 25cm have been considered to be contaminated with the radionuclides by considering that the source was released from the clean cover to the saturated zone through depth 0-25cm. The soil layers were categorized as, primary contamination, un-saturated zone and saturated zone.

2.2.2 Reporting time

The reporting time for the estimation of radiological dose for individuals residing off-site has been considered 8, 16, 24, 32, 40, 48, 56, 64, 72, and 80 years, as input file, in the RESRAD-OFF site code.

2.2.3 On-site and Off-site areas

The on-site area around the source term is considered as 100 hectors (1000000 m^2), which is divided into co-ordinates, x-axis (1000 m) and y-axis (1000m),from literature [13]. The physical features of the on-site area e.g. fruit, grain, non-leafy vegetable plot (along x-axis is 0.003125% and along y-axis is 0.0032%), leafy vegetable plot (along x-axis is 0.003125% and along y-axis is 0.0042%), pasture, silage growing area (along x-axis is 0.01% and along y-axis is 0.01%), grain fields (along x-axis is 0.01% and along y-axis is 0.01%) ,dwelling site (along x-axis is 0.003125% and along y-axis is 0.0032%) and surface water body(along x-axis is 0.03% and along y-axis is 0.03%), form literature [13].

For the off-site area the total area occupied by the off-site location is 100 hectors (1000000m^2). This off-site area for the receptor is divided into the co-ordinates-axis (1000m) and y-axis (1000m). The physical features of the off-site area e.g. the receptors spends time on the primary contamination in indoors and the outdoors is zero. Time spent by the receptor on the off-site dwelling area (indoor is 50% and outdoor is 10%). The receptors spends time on the farmed areas (which may lie on the primary and the secondary area) in fruit, grain, and no-leafy field and leafy vegetables fields and pasture and silage fields and livestock grain fields is 10% from literature [13].

2.3 Exposure Pathways

In the exposure pathways five different exposure scenarios has been considered. In the first scenario, the radiological doses has been calculated by considering the all pathways (external gamma, inhalation, plant ingestion, meat ingestion, milk ingestion, drinking water and soil ingestion), using default inputs as defined by the RESRAD-OFF site code. In the second scenario, the radiological doses has been calculated by considering the all pathways (external gamma, inhalation, plant ingestion, meat ingestion, milk ingestion, drinking water and soil ingestion) using the model input parameters as used in literature [14]. In the third scenario, the radiological doses has been calculated by considering the all pathways (external gamma, inhalation, plant ingestion, meat ingestion, milk ingestion, drinking water and soil ingestion) using site specific data from the literature [1-13]. In the fourth scenario, the radiological doses calculated from the scenario-1, scenario-2 and the scenario-3 has been compared with the literature [13], for finding the maximum and the minimum dose due to the considered locations and for the site soil parameters of the different sites. In the last one, the radiological dose has been calculated using default input and for each exposure pathway to identify the contribution of each pathway to the cumulative doses to the individual.

2.4 Assumptions

Following assumption are made for the processing of the site soil specific data

i. Some of the parameters such as irrigation applied per year, weather conditions were not available on the annual base, so these conditions would be taken as constant.
ii. For the weathering conditions, agricultural, livestock, feed growing area and off site dwelling area parameters were considered to be same for each year.
iii. The radionuclide concentration in the soil was considered to uniform over the specified area.
iv. The ground water transport radionuclide parameters were considered to be uniform from the primary contamination to the un-saturated and saturated zones.
v. The distribution and release rate of the radionuclides over the three layers was considered same.
vi. The parameters (aquifer flow, irrigation, rain-fall factor, dry bulk density cover and management factor) values specified for the contaminated zone was same for all the radionuclide in the primary contamination.
vii. The reporting time for all the radionuclides was same.

2.5 Calculation Duration

To identify the severe effects of the radiological dose at the place on the offsite location, the zones where the radiological effects are most affective and common and the calculation duration was considered for 72 years.

3. Results and Discussions

3.1 Scenario I

In this scenario, the mean total dose equivalent to an individual for seventy two years, using default inputs, as defined by the RESRAD-OFF site code has been estimated and is presented in the Fig. 3, considering the all pathways (external gamma, inhalation of dust particles, plant ingestion, meat ingestion, milk ingestion, drinking water and soil ingestion). From the data analysis, the maximum total effective dose 1.606E-01(mSv) has been recorded. The cumulative dose has a fluctuating trend over time.

3.2 Scenario II

In this scenario, the mean total dose equivalent to an individual for seventy two years, using the model input parameters as used in the literature [13] has been estimated and is presented in the Fig. 3, considering the all pathways (external gamma, inhalation of dust particles, plant ingestion, meat ingestion, milk ingestion, drinking water and soil ingestion). From the dose inclination analysis, the maximum total effective dose 6.939E-01(mSv) has been recorded. The cumulative dose has a fluctuating trend over time.

3.3 Scenario III

In this scenario, the mean total dose equivalent to an individual for seventy two years, by considering all pathways using site specific data from the literature [1-14] at NIAB has been estimated and is presented in the Fig. 3, considering the all pathways (external gamma, inhalation of dust particles, plant ingestion, meat ingestion milk ingestion, drinking water and soil ingestion). From the dose inclination analysis, the maximum total effective dose 9.120E-02(mSv) has been recorded. The cumulative dose has a fluctuating trend over time.

3.4 Scenario IV

In this scenario, the mean total dose equivalent to an individual for seventy two years, by considering the results from all the three scenarios has been estimated. From the data analysis, it is observed that the maximum dose of 6.939E-01 (mSv) has been recorded at 72 years, and the minimum dose of 0.00005E-5 (mSv) has been recorded at (0-7) years, by comparing all output results of the scenario-1, scenario-2 and scenario-3. This overall result for maximum dose was compared with literature [13], 0.23 (mSv) on the annual basis. The dose has fluctuating trend over time.

3.5 Scenario V

In last scenario, the mean total dose equivalent has been estimated by considering all pathways for the cumulative doses to the individual and are presented in the Fig. 3. The maximum dose for scenario-1, scenario-2, scenario-3 and literature [13], was observed 1.606E-01(mSv), 6.939E-01(mSv), 9.120E-02(mSv) at 72 years, 0.23(mSv) on the annual basis and the minimum dose for the scenario-1, scenario-2 and scenario-3, was observed 1.207E-01(mSv), 5.000E-05(mSv) and 5.23E-02(mSv) at (0-7) years.

In the above Fig. 3, the scenario-2 has a fluctuating trend, because when initially the dose rate decrease with time when the time increased. The radiological dose increase with time, due to the leaching of the radionuclides to the ground water and increase the in growth progeny of the parent radionuclides and also due to the distribution factors and the erosion rates and the removal of the clean cover from the primary contamination. So after this passage of time radiological dose decrease with time by the decaying of the parent and daughters radionuclides.

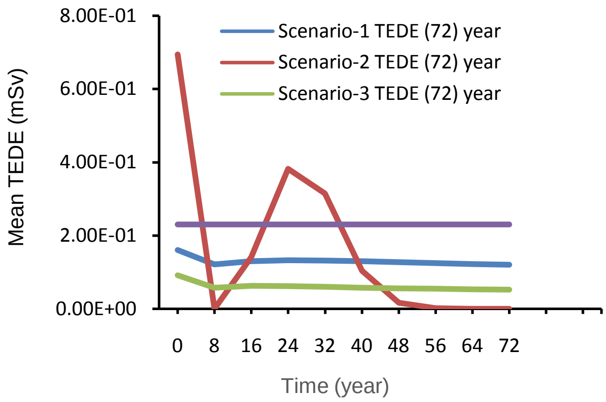

Fig. 3: Cumulative Results (Scenario-1, Scenario-2, Scenario-3 and, Scenario-4 [Mean TEDE with all Pathways (72hrs)]

4. Conclusions

From the data analysis presented in Fig. 3, the total mean effective dose were estimated, using site specific data as input parameters(aquifer flow, irrigation, rain-fall factor, dry bulk density cover and management factor), for the site of NIAB, Faisalabad. Based on the data analysis, the execution of the RESRAD-OFF site code, the maximum dose of 9.120E-02 (mSv) was observed, for 72 years. This dose limit is very smaller as compared with the literature (0.23mSv) and the world average basic radiation dose limit of 1 mSv. It was also observed the minimum dose of 1.207E-01 at seventy two years.

Table 1: Output Results of Scenario-1 (TEDE for all nuclides in 72 years)

Time ‘t’ (years)	TDOSE(t) (mSv/y)
0	1.606E-01
8	1.218E-01
16	1.299E-01
24	1.331E-01
32	1.322E-01
40	1.299E-01
48	1.274E-01
56	1.249E-01
64	1.227E-01
72	1.207E-01

Table 2: output Results of Scenario-2 (TEDE for all nuclides in 72 years)

Time ‘t’ (years)	TDOSE(t) (mSv/y)
0	6.939E-01
8	2.584E-04
16	1.410E-01
24	3.822E-01
32	3.150E-01
40	1.041E-01
48	1.655E-02
56	1.699E-03
64	1.917E-04
72	5.000E-05

Table 3: Output Results of Scenario-3 (TEDE for all nuclides in 72 years)

Time ‘t’ (years)	TDOSE(t) (mSv/y)
0	9.120E-02
8	5.707E-02
16	6.235E-02
24	6.185E-02
32	5.974E-02
40	5.763E-02
48	5.589E-02
56	5.454E-02
64	5.352E-02
72	5.275E-02

Table 4: Output Results of Scenario-4 (TEDE for all nuclides in 1 year)

Time ‘t’ (year)	TDOSE(t) (mSv/y)
01	0.23

The total mean effective dose was estimated, using model input parameters as used in the literature [14]. Based on the data analysis, used for the execution of the RESRAD-OFF site code the maximum dose of 2.34E-01, for 72 year, (mSv) was observed. This dose limit is much lower as compared on the basis of annual dose limit (0.23mSv), literature [13].The maximum dose in this scenario is lower than the world average dose rate of 1 (mSv).It was also observed the minimum dose of 3.5E-04 at seventy two year. The difference in doses is due to difference in site specific parameters in both the scenarios.

Through the analysis of, the total mean effective dose, using site specific parameters of the of the site NIAB, Faisalabad, Based on the data analysis, used for the execution of the RESRAD-OFF site code the maximum dose of 9.120E-02 (mSv) was observed at (0-7) years. This dose limit is much lower as compared with the dose in literature [13]. The maximum dose in this scenario is less than the world average dose rate of 1 (mSv).

From the results, it can be observed that initially the dose rate decrease with time when the time increased. The radiological dose increase with time, due to the leaching of the radionuclides to the ground water and increase the in growth progeny of the parent radionuclides and also due to the distribution factors and the erosion rates and the removal of the clean cover from the primary contamination. So after this passage of time radiological dose decrease with time by the decaying of the parent and daughters radionuclides.

Through the analysis, it can be seen that, in literature [13] the maximum dose received by an individual while using the site specific parameters at the site of NIAB, the dose received by an individual is lower as compared to the literature [1-12 & 14] .

From the estimated results, it is concluded that the RESRAD-OFF site code is a very convenient code for the estimation of the radiological doses however; accuracy in the estimation could be increased by using site specific input parameters accurately on the annual basis.

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